## VARIATION IN TWO SPECIES OF LUCIDELLA FROM JAMAICA.

BY AMOS P. BROWN.

The genus *Lucidella* is best known from species found in the island of Jamaica, from which locality the first species were figured by Férrusac[1] under the name of *Helix aureola*. Férrusac then figures the two common species of Jamaica, which appear to have a general distribution throughout most parts of the island. These species are very plentiful in the interior of the island, particularly in the Mandeville region. They live in the more undisturbed parts along the borders of woods, seeming to prefer situations where there is a certain amount of sun, rather than in the dense woods. Along the roads they are met with inhabiting the stone walls, which are the common fences in this part of the island. When once established in the walls they appear to flourish, even when the woods are cut away from the vicinity of the roads, and where they have plenty of cover and not too much dryness they develop into as large forms as in the more undisturbed regions. *Lucidella aureola* (Fér.) is probably more generally and widely distributed, but *L. granulosa* C. B. Adams is more plentiful in the Mandeville country, though both forms are found living together. Along grassy roadsides with low limestone rock exposures and even where the red residual clay from the limestone forms the banks of the road they are found in numbers; in the case of the red clay banks, perhaps *L. aureola* is somewhat more common, while *L. granulosa* is found more frequently in numbers where the limestone exposures are seen. This habit of living along the borders of woods and in the more open rocky woods is common with both species in the more undisturbed regions where the original forest still exists.

These two species have adapted themselves to the conditions brought about by advancing civilization and clearing of the land, and are well established, even in the oldest settled districts, being found in numbers in many places that have been quite stripped of

[1] D. de Férrusac and G. P. Deshayes, *Hist. Nat. des Mollusques*, Vol. 3, 1820–1851, Pl. 48, 1, three figures of *Lucidella aureola* (Fér.) and Pl. 49A, 1, two figures of *L. granulosa* C. B. Adams, all figured by Férrusac under the name of *Helix aureola.*

the original forest. But it is to be noted that it is in these places, where the woods have been cleared for a long period of years, that a reduction not in numbers of individuals, but in size may be observed. While the evidence is not entirely complete, it seems to point to a reduction in size in those places where the forest has been entirely cleared away and where the animals are now living *under conditions of greater dryness* than the *optimum* conditions that obtain in places where the original forest is still more or less undisturbed. The variations treated of in this paper are seen in individuals of these species that are living under the *optimum* conditions which obtain in the forested sections, as contrasted with those individuals which are found in the dryer, cleared sections. The localities from which these contrasted individuals were obtained are in Manchester Parish, near Mandeville for *L. granulosa;* and for *L. aureola*, the same region as contrasted with the Montego Bay district.

*Lucidella granulosa* is found almost everywhere in the region about Mandeville where the conditions are favorable. It is in this locality much more common than *L. aureola*, which, however, is found plentifully in this part of Manchester. But *L. granulosa* was not taken at Montego Bay, while a small form of *L. aureola* was very plentiful at this station. Perhaps the most typical forms of *L. granulosa* come from the borders of the undisturbed woods in Manchester Parish near Mandeville, and it seems likely that it was from this region that C. B. Adams first collected the form. From the many colonies in the Mandeville region from which I collected these typical forms of this species the Somerset, Somerset Road, and Benmore woods colonies may be selected as furnishing characteristic examples of the normal form. These localities have been described in a former paper;[2] it will suffice here to state that they were places where the original forest still exists and *optimum* conditions for the growth of this species obtain. The small forms that are compared with these typical forms were collected at two stations where the forest had been completely cleared, at least near the roads along which the collecting was done, and were near the Sturridge place, some three miles to the southeast of Mandeville village, and along the Kendal Road,[3] one mile to the north of the town. A short description of these stations will be necessary.

---

[2] Brown, Variation in some Jamaican Species of Pleurodonte, these PROCEEDINGS, 1911, pp. 124, 128, 129.

[3] See map of Mandeville region, *loc. cit.* these PROCEEDINGS, 1911, p. 121.

The Sturridge place, about three miles to the southeast of Mandeville, is in the old settled part of the region. Here the original forest has long been cleared, and the country is almost bare of shade trees. A few scattered orange or pimento trees along the roadsides are the only protection from the tropical sun, and the bare fields, while grassy, have an arid look as compared to the dense woods of the original forest. The only cover for the mollusks is in the stone walls, which, as usual, are built along the roads as fences. An old private burying-ground, doubtless belonging to the Sturridge place, had a few trees growing in it which made a little shade and this old cemetery wall was the most favorable place for mollusks that was found at this point. Here and at a few places nearby along the road specimens of *L. granulosa* were obtained. They were not very plentiful, but were found in fair numbers, and in as great numbers as any other species of mollusk collected at this point. They were quite uniformly small specimens. They inhabited the wall, utilizing its cover, and were collected from the wall and from the ground at its base.

The other station where the small form of *L. granulosa* was taken was on the Kendal Road, one mile north of Mandeville; along a part of the road through pasture lands where the trees had been cleared back from the road on the more level ground, so that there was but little shade along the road. Here again the Lucidellas were living in the low stone walls which lined the road and were especially abundant in places where the top of the wall was covered with moss or fern. Here the dead shells of this small form of *L. granulosa* were very plentiful, many in very fresh condition, but, during the dry time when I was collecting, no living individuals were seen moving about. They had apparently come up on the tops of the walls to escape from the rain during wet weather and died there. At this place the only cover for the snails was to be found in the wall itself. This, as in the case of the Sturridge place, must have been very dry except after a shower or during the rather uncertain rainy seasons. This small form of *L. granulosa* is well established at this station, but only the small individuals were seen, as was the case at the Sturridge place. It is practically a small local race at each locality.

While not so plentiful as *L. granulosa* in the Mandeville region, *L. aureola* is found almost everywhere that the conditions are favorable. This species lives on the ground and is found on grassy banks, even where there is no rock. It does not require rock piles or walls

for cover, evidently grassy pastures offering sufficient cover and food for the species. This probably explains its present wide distribution, as compared with *L. granulosa*, and its persisting in places where the other species are not now found. It occurred along the borders of the woods in the Somerset region and along the roadsides at almost all places about Mandeville, especially being collected along the Lower Santa Cruz Road in considerable numbers. Here it was living on the grassy borders of the road, and was taken from the clay banks in places where, for instance, *Cepolis* (*Hemitrochus*) *graminicola* was common. Along this Santa Cruz road the forest is mostly cleared, but the *L. aureola* has sufficient cover in the grass of the pastures which the road passes through. Both here and especially at Somerset, two places selected as furnishing normal forms of the species, the animals are living under what may be termed *optimum* conditions. Nowhere in the Mandeville region, in fact (except perhaps near the Sturridge place, where *L. aureola* was not found), are the fields really arid and, for a form that can live on the ground with only grass for cover, the conditions are perhaps never very unfavorable. A small form of this species is found at Montego Bay, a region where the soil is so thin that the clearing of the forest has resulted in the development of conditions that may be described as arid, at least during the dry part of the year. Montego Bay is one of the oldest settlements in the island, dating back to the Spanish occupation. The original forest has been cleared off all of the more level ground, which has been under cultivation for probably the greater part of a century. Where trees have been planted, they are mostly logwood, which is grown in the pastures; the trees being planted sufficiently far apart to allow the pasture grass plenty of sun. In these logwood plantations, especially if they are on a slope, the soil is very thin and the rock comes near the surface. During the dry season the ground gets very parched and the grass quite brown; in the wet season, from the end of April to the end of November, when showers may occur at any time, the torrential rains almost immediately drain off on the hill slopes, and owing to the porous character of the soil the ground becomes quite dry between the showers. For a great part of the year, except when a rainy week may occur in May or November, any mollusks that are ground dwellers must exist under alternating short periods of great moisture and dryness, while during the dry season, from December to April, they must æstivate under the almost arid conditions which obtain.

**Lucidella granulosa** C. B. Adams. Plate I, figs 1–15.

*Helix aureola* var. Fér., Nat. Hist. des Mollusques, Vol. 3, 1820–1851, Pl. 49A, two figures marked 1.
*Helicina aureola* Gray, Zool. Jour., 1, p. 70, pl. 6, fig. 15.
*Lucidella aureola* var. *granulosa* C. B. Ad., Cont. Conch., 6, 1850, p. 89.
*Lucidella undulata* Pfr., Malak., Bl. VIII, 1861, p. 171.

This is the species usually labelled *L. undulata* in collections. It was first figured by Férrusac along with *L. aureola* under the name *Helicina aureola*. The two figures on Férrusac's plate 49A numbered 1 represent a form covered with granules which he considered to be a variety of *Helix aureola* and which is the common species of *Lucidella* in the Manchester district. C. B. Adams refers to this form as follows: "A variety of *Lucidella aureola* is so strongly sculptured with granules that it will be convenient to designate the variety with the name of *granulosa*." (Adams, *loc. cit.*) This was in 1850, and eleven years afterwards, in 1861, Pfeiffer describes this form, referring to Férrusac's figure above mentioned, under the name of *L. undulata*. It is by this name of Pfeiffer's that the species is generally known, although the *granulosa* of Adams antedates Pfeiffer's name by eleven years. Inasmuch as C. B. Adams collected in the Mandeville region in Manchester, it is very likely that his *granulosa* came from this district. In a former paper[4] it is recorded in the Mandeville region from Benmore, Bloomfield, Sturridge place, Cedar Hill, Lower Santa Cruz Road, ridge near Lincoln, Somerset, Somerset Road, and it was also collected on the Kendal Road north of Mandeville as well as several other places in this vicinity. Most of the specimens of this species in the A. N. S. P. Collection were taken by me in 1910, but there are three or four trays simply recorded as from "Jamaica," one of which marked "Swift Collection" is of especial interest. This lot probably came from H. Vendries, of Kingston, and is marked on the collector's label "*L. aureola* Fér. var. *granulosa*"; they possess the characters which seem to distinguish this species in a pronounced degree. If these are Vendries specimens they no doubt came from St. Andrews Parish. They may be described as follows:

**Lucidella granulosa** C. B. Ad. (Swift Collecton A. N. S. P.) Plate I, figs 1–3.

Shell somewhat convexly conoidal, rather thick, somewhat keeled on the periphery and wrinkled, in the direction of the growth lines, radially from the apex; color reddish-brown, mottled with whitish; of about 6 whorls; sculpture of raised spiral lines or liræ,

[4] Pilsbry and Brown: The Mollusca of Mandeville, Jamaica, and its Environs, Proc. A. N. S. P., 1910, pp. 510–535; *Lucidella undulata* Pfr. p. 525.

covering the entire surface, those above the periphery being swollen at intervals, when crossed by the radial wrinkles or corrugations that follow the growth lines, thus forming both the raised granulation and the whitish spots, from the raised liræ becoming whitish where swollen. The swelling of the revolving spirals becomes very pronounced along the periphery, which is thus raised into a series of tubercles, commencing about the beginning of the fourth whorl and continuing to the lip. The swelling of the liræ to form the granulation does not extend far below the periphery, not more than 4 or 5 of the revolving striæ being thus affected. The striæ continue, however, to the umbilicus, becoming fainter as this is approached. Diam. 7.7, alt. 5.5 mm.

The keeled and tuberculated periphery seems to be characteristic of this species, but is not always, as in this Swift Collection lot, carried out to the lip. It is present in the young shells in all cases, which would seem to indicate that the ancestral species must have resembled this one from the Swift Collection. None of the Mandeville region specimens normally show this tuberculated and keeled periphery in the adult state, at least not entirely up to the lip; but the young all show it. The Somerset Road specimens (Plate I, figs. 6, 10), which perhaps lived under as nearly *optimum* conditions for this species as any collected in the Mandeville region, show this tuberculated and keeled periphery up to nearly the end of the fifth whorl, but the peripheral tuberculation dies away before the sixth whorl is reached. Young shells from this station have quite a different appearance from the adults. This seems, as above stated, to be the general condition of the species in the Manchester region, the adult stage has lost the peripheral granulation, but the younger stages show it. And it is perhaps more pronounced in the Somerset specimens than in any of the others, the last whorl being frequently nearly smooth (Plate I, fig. 4, figs. 7–9), on the periphery. An exceptional specimen from Somerset, showing the tuberculated periphery, is figured at 5 on the plate. The tuberculate condition of the periphery extends from the middle of the third whorl (2.5 whorls from the apex) to the middle of the fifth whorl (4.5 whorls from the apex). Thus the last whorl (there are five and one-half to six whorls) is comparatively smooth on the periphery, and, except for the color pattern, the shell at first sight resembles *L. aureola*. The color pattern itself varies when the peripheral tuberculation disappears; when it is present there is a regular periodicity in the recurrence of the whitish patches which

mark the swelling of the liræ that is the cause of the lighter spots, they run from 16 to 20 to the whorl, and when this periodicity is seen with the whitish spots reaching the periphery, this in turn becomes tuberculated and keeled. This regularity of the markings is characteristic of the younger stages, and as long as it is seen the young shell will be found to be keeled and tuberculated; when it disappears and the color pattern becomes a mottling of the shell, then the periphery is neither keeled nor tuberculated. In the two places where dwarfed shells were taken, a large number of them have this tuberculated and keeled periphery on the last whorl, although considerably less than half are so ornamented. It is noticeable that the whitish ornamentation, when it is accompanied by the peripheral tuberculation, follows the growth lines, and is then more continuous and stronger. But when it curves towards the mouth of the shell and crosses the growth lines, it tends to break up into branches, rarely reaches the periphery, and practically never causes tuberculation. When the animals are living under *optimum* conditions, as at the Somerset and Somerset Road stations, this bending forward of the ornamentation across the growth lines becomes characteristic, and the color pattern becomes finer and less regular by the branching of these whitish lines or by their breaking up into dots. And where this finely mottled color pattern is seen, the last whorl is nearly smooth and the periphery is free from tubercles.

The tuberculated condition of the periphery is thus a character of the young stages, sometimes continued into the adult stages up to the development of the lip. The appearance of this character in the dwarfed races (Plate I, figs. 11–15) at Kendal Road station and at the Sturridge station is due to what is generally described as "reversion to an ancestral form"; or it is due to the animals, living under unfavorable conditions as regards shell development and growth, which causes them to mature at an earlier stage than those forms which live under *optimum* conditions. But while the conditions are unfavorable to growth, they are not unfavorable to reproduction, for these dwarfed forms are very plentiful at the localities where they were taken. An examination of the shells of these Kendal Road and Sturridge forms will show at once from the growth lines that they grew with many interruptions, as many as 30 such interruptions being often seen in one shell. Those from Kendal Road station also mature earlier, as they have only five whorls, instead of five and one-half or six, as in forms growing under more favorable conditions. The forms that live in walls, whether

of this species or any other, where the wall is their only cover, are always subject to such recurring periods of enforced inactivity, during dry spells and with the long period of the dry season, which may last for several months, during which the sexual organs probably mature. These wall dwellers become active after every shower, and probably æstivate temporarily during the dry spells between showers, so they have many less growing days throughout the year than forms that may move about and feed any day. Each æstivation period is marked by a pronounced growth line, and the 30 or more such interruptions mentioned above are thus recorded. If the adult stage is reached by the animal before the shell has passed through the tuberculated-and-keeled periphery stage of shell growth, then the adult, with lip developed, has this tuberculated periphery; if this stage has been passed the last whorl is smooth and not tuberculated along the periphery. In the Sturridge place forms, where the whorls may reach five and one-half, but few show the tuberculation of the periphery extending out to the lip.

**Lucidella aureola** (Fér.). Plate I, figs. 16–26.

*Helix aureola* Férrusac, Nat. Hist. des Mollusques, Vol. 3, 1820–1851, Pl. 48, fig. 1 (not. Pl. 49A, 1).

*Helicina* (*Lucidella*) *aureola* Sow., Thes., Vol. III, p. 282, No. 56, figs. 94, 479.

*Lucidella aureola* Swainson, Chemn. ed. nov., Pl. 5, figs. 20–23.

This is the most widely distributed species of *Lucidella* in the island of Jamaica, but it generally occurs in small numbers at any one station. Specimens of this species were examined that were collected in Portland (Port Antonio), St. Andrews (Stony Hill and Constant Spring), St. Catharine (Natural Bridge, Bog Walk), Manchester (various points near Mandeville), and St. James (Montego Bay at Orange Hill and Rose Mount) as well as a number of other collections of which the locality was not recorded further than as from "Jamaica." Among these, the race from St. James as found at Orange Hill and Rose Mount is a small, dwarfed form which is different from any seen elsewhere, and is only matched in size by an occasional specimen from the region to the southwest of Mandeville, along the Santa Cruz road. With the exception of this St. James race from the vicinity of Montego Bay, the general description of the species (Plate I, figs. 16–21) is as follows:

Shell depressed conoidal, spire somewhat convex, apex mucronate; uniformly colored some shade of chestnut, paler in the young shells; the shell sculptured with fine revolving liræ and the whorls crossed by oblique wrinkles which follow the growth lines in direction,

beginning to appear generally on the second whorl and sometimes continuing to the lip, but dying away towards the periphery, or, if they cross it, not producing a thickening of the liræ at this point. Whorls six or somewhat over (6.3) and rarely less than 5.7. The revolving striæ become fainter and are almost obsolete in the umbilicus. The number of these revolving striæ varies through the appearance of interstitial liræ between those already existing, which eventually develop to the same size as the others. There are generally about 45 liræ on the last whorl, of which 18 or 20 are above the periphery, they are close and even and are not thickened where the oblique wrinkles cross them. The size varies with the locality, ranging from diam.=10 mm. by alt.=7.7 mm. (Pfeiffer) to diam.=5.6 mm. by alt.=4.3 in the smallest specimen taken in the vicinity of Mandeville.

This smallest specimen, which came from the Lower Santa Cruz Road about three miles from Mandeville is simply a diminutive reproduction of the largest which was found at Somerset, with somewhat fewer whorls but with none of the peripheral granulation observed on some of the Montego Bay specimens (Plate I, figs. 22–26). These latter, which, as stated above, were collected on the Orange Hill and the Rose Mount estates, differ from the typical *L. aureola* above described in certain specimens. In about one-half of the Orange Hill specimens and about one-third of the Rose Mount specimens an additional sculptural feature is present. The periphery of the last whorl is raised into a series of points or tubercles, by the thickening of one or more of the peripheral liræ where they are crossed by the transverse oblique wrinkles which are present in all specimens of this species examined. This structure is exactly comparable to the development of the granulate sculpture on *L. granulosa* which has been described. A careful examination of the young of typical *L. aureola* from some fifteen localities shows that while the oblique transverse wrinkles are common to all of them, these do not produce any granulation on the periphery, so that this is not, as in the case of the dwarfed races of *L. granulosa*, a "reversion" or the effect of the individual's maturing at what is normally a young stage, but actually a new sculptural character which has developed in these Montego Bay forms. It only appears distinctly on the last whorl, the tubercles becoming stronger after the periphery emerges from the suture, but it may be present on the preceding whorl also, as the corrugations or wrinkles are found well developed on both the last and next to the last whorls. When well developed,

the granulations continue out to the lip; sometimes they only appear in the middle part of the last whorl and become obsolescent towards the lip. They are well shown and their connection with the transverse wrinkles is apparent in the figs. 22, 25, 26, Plate I. This peripheral granulation is thus characteristic of certain of the specimens taken at Orange Hill and Rose Mount, Montego Bay, and is not found in the normal *L. aureola* from any other locality examined. The forms possessing it might be designated by a varietal name, as *montegoensis*, and it is probably the beginning of a new species, or what would become one if the forms continued to live at the Montego Bay localities, which, unless the settling up of the country continues, is likely to be the case, they having survived the advance of civilization for perhaps a century. But it may be a variation not due directly to the aridity of the country produced by the clearing of the land—not referable to change of environment alone—but to *hybridity*, and this might work out in future generations.

We thus have two species, each developing a dwarfed race under similar conditions of environment, but in which the causes for the development of the new sculptural characters which accompany the dwarfing are probably not referable to the same causes.

## The Variation in Size.

The amount of the variation in size may be graphically shown by plotting the dimensions of the forms to scale in the manner adopted in a previous paper.[5] These dimensions are given below.

*Variation in size in Lucidella granulosa C. B. Adams.*—The forms of this species compared in fig. 1 are from Somerset, Somerset Road, Benmore, Kendal Road one mile north of Mandeville, and the Sturridge place, three miles southeast of Mandeville. Those from Somerset and Somerset Road are the largest, those from Kendal Road and the Sturridge place the smallest. The Benmore specimens lie between these two, but nearer to the larger group, so that the plot shows two groups as to size, with a gap between the two that is not entirely bridged over by the Benmore specimens. The normal forms, represented by the group of larger specimens from these localities, show some variation in the sculpture, but are in general as described above for the forms from Somerset and Somerset Road, with a nearly non-tuberculated periphery on the last whorl. Only

[5] A. P. Brown, Variation in some Jamaican Species of Pleurodonte, Proc. A. N. S. P., 1911, pp. 117–164 figs. 2–14.

a few of the Somerset specimens show the keeled and tuberculated periphery that is characteristic of the Swift Collection specimens, of which a description is given above. These are, however, of normal size for the species, as may be seen from the plate (figs. 4, 5, 7–9). A few individuals from Benmore show this tuberculated periphery also.

Contrasted with this smooth condition of the last whorls, which may be considered normal for *L. granulosa* as found near Mandeville, is the much larger proportion of tuberculated-keeled forms found

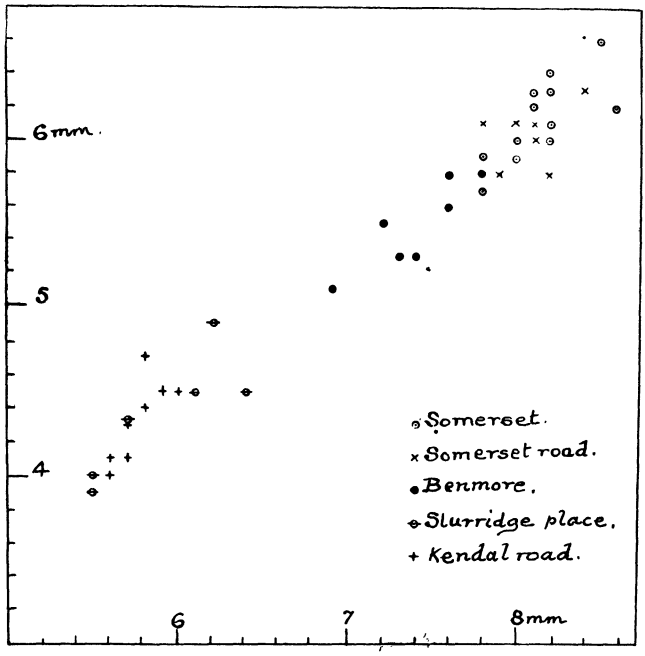



Fig. 1.—*Lucidella granulosa.* Comparison of the dimensions of the forms from five different localities.

among the specimens from the two localities where the forms are dwarfed. At the Sturridge place, about one-half of the specimens show peripheral granules on the last whorl, though these tend to become obsolescent as the lip is approached. In the Kendal Road specimens somewhat over two-thirds show this granulation, and in many cases it extends out to the lip, a much smaller proportion showing this granulation of the peripheral lira becoming obsolescent and dying away as the lip is approached than in the case of

the Sturridge specimens. The reduction in size in *L. granulosa* in these localities is accompanied by a slight reduction in the size of the embryonic shell or protoconch, which is easily observed in all cases in the adult shell. The minor diameter of the protoconch averages 0.47 mm. in the specimens from the larger group, the average being for the Benmore specimens 0.444 mm., for the Somerset Road specimens 0.47 mm., and for the Somerset specimens 0.50 mm.; as against an average of 0.416 mm. for the Kendal Road specimens and 0.408 for the Sturridge place forms. There is thus a dwarfing that is not alone individual, but a racial dwarfing. These characters are well shown by a comparison of the dimensions by whorls which is given in fig. 2. A series of characteristic specimens were selected from each locality and each individual measured by whorls with an

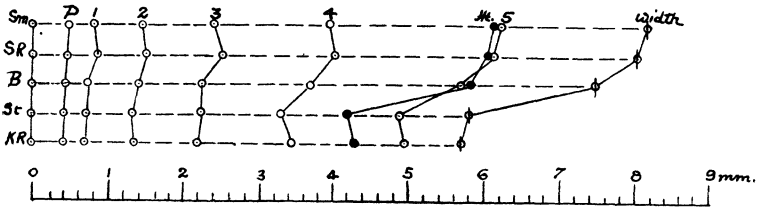



Fig. 2.—*Lucidella granulosa*. Comparison of width and height by whorls. Sm. = Somerset, S. R. = Somerset Road, B. = Benmore, St. = Sturridge, K. R. = Kendal Road.

eyepiece micrometer on the microscope, using of course a mechanical stage to adjust the specimen. The measurements by whorls and the minor diameter of the protoconch are plotted in the figure. This last character hardly shows well at this scale, the differences being small. The comparison by whorls brings out the fact that in spite of the dwarfed character of two of these races, but little reduction in size is shown up to the third whorl and the difference in size only becomes pronounced at the fourth whorl. All of these forms, whether normal or dwarfed, possess at least five whorls, so that up to this point the growth rate is strictly comparable. The marked falling off in size of the two dwarfed races at this point is to be attributed to the environment alone. The still more marked falling off in diameter as shown in the last whorl is partly due to a reduction in the number of whorls in the dwarfed races, this falling from the maximum of somewhat over six whorls in the larger forms from Somerset, Somerset Road, and Benmore to between five and six

for the two dwarfed races from Sturridge's and Kendal Road, although even at these two localities the whorls may reach six in some cases.

*Variation in size in Lucidella aureola* (*Fér.*).—The forms of this species compared in fig. 3 are from Somerset, Santa Cruz Road and Orange Hill, Montego Bay; and to these has been added a series from the A. N. S. P. old collection labelled simply "Swift Collection," and recorded as from "Jamaica" without any definite locality. These divide at once into two groups, of which the Somerset,

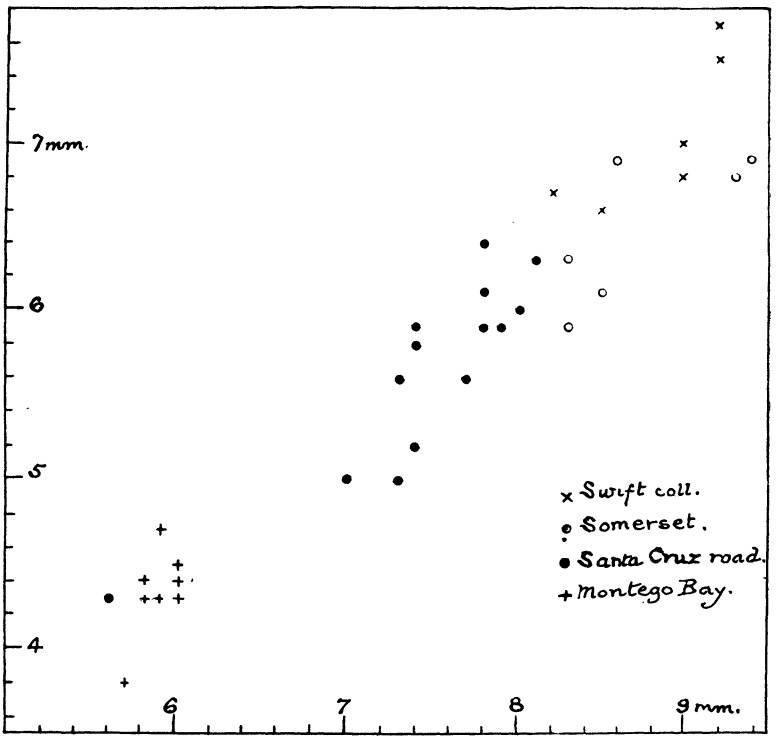



Fig. 3.—*Lucidella aureola.* Comparison of the dimensions of the species from four different localities.

Swift Collection, and Santa Cruz Road lots are larger, the Montego Bay lot is smaller. It will be seen, however, that a single specimen from the Santa Cruz Road series approaches the Montego Bay specimens in size, being of less diameter than any of this Orange Hill (Montego Bay) series. The Swift Collection series are all proportionately higher than those from Somerset, which otherwise they compare well with in size. The Santa Cruz specimens lived

in the open fields and in walls along the roadside, their only cover being the walls or the low vegetation of the fields, and they are all smaller than the Somerset and Swift Collection series. The one exceptionally small specimen was adult, so far as development of the lip was concerned, and in size would correspond to Pfeiffer's variety which he calls *L. aureola minor*, being even smaller than his dimensions for that form. But while it compares in size with the Montego Bay forms, it is not at all like them in sculpture, resembling the normal *L. aureola* of the island generally. It is evident, then, that the normal *L. aureola* may vary in size in occasional individuals down to that of the dwarfed or "runt" race found near Montego Bay. This last race is a composite one, in about one-half of the Orange Hill specimens and one-third of the Rose Mount specimens a distinctive sculpture characterizes the forms. This has already been described above. The minor diameter of the protoconch is also somewhat less than in the normal forms of this species, this dimension varies from 0.55 mm. in the Somerset and Swift Col-

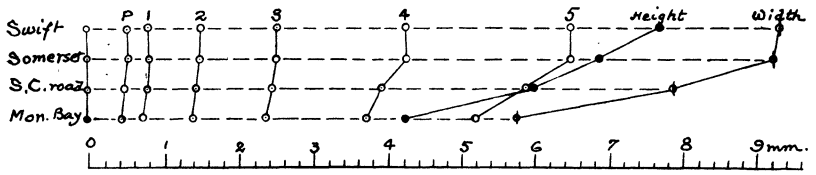



Fig. 4.—*Lucidella aureola.* Comparison of the width and height by whorls from four different localities.

lection specimens to 0.50 mm. in the Santa Cruz Road specimens and 0.45 mm. in those from Montego Bay.

A comparison of the dimensions of *L. aureola* by whorls is given in fig. 4, where these protoconch diameters are plotted along with the heights. It will be seen that the diameters by whorls do not show much variation in the four lots of specimens examined until the third whorl is passed, but a marked falling off in the diameter of the Santa Cruz Road and the Montego Bay specimens commences with the fourth whorl, becomes still more pronounced in the fifth whorl and culminates in the last whorl. As in the case of *L. granulosa*, there is a reduction in the number of whorls in the adult stage in the case of the dwarfed Montego Bay forms which accentuates the diminution in diameter after the fifth whorl. The number of whorls is of course larger in the larger specimens from Somerset, the Swift Collection lot and the Santa Cruz Road specimens, being generally over six whorls, whereas the specimens from Montego Bay

range from five to five and three-tenths whorls, and in rare cases one may reach five and one-half whorls. As in the case of *L. granulosa*, the reduction in size is accompanied by a reduction in the number of whorls, and the animal matures at an earlier stage of shell development than is the case in the larger normal forms. The small specimen from Santa Cruz Road which approximates in size the Montego Bay specimens had only five and three-tenths whorls, as they have, and a few other Santa Cruz Road specimens, which are small, run about five and seven-tenths whorls.

### The Causes of the Variation in Size and Sculpture.

In the case of the variation of the two species herein described it is plain that we have to deal with two different kinds of variation: (1) A reduction in size from the normal type and (2) a change of sculpture. The cause of the change of size is the same in both cases and has already been stated. The reduction in size is undoubtedly brought about by the drier and more arid environment which retards the growth of the individual; superimposed upon which is the regular periodicity of climatic changes due to the changing seasons, which induces the development of the reproductive organs at a given time in the year, without much regard to the size the individual has attained. Thus the forms living under arid conditions will have only reached the beginning of the sixth whorl (or passed the completion of the fifth whorl) when the enforced æstivation brought on by the dry season commences. During the dry season all of these snails are more or less inactive, and during this resting stage the genitalia are developed. The lip probably commences to develop about the same time. Forms living under *optimum* conditions have reached the beginning of the seventh whorl when this occurs; they will have an extra whorl as compared with the forms living under arid conditions, which would have had many less feeding and growing days, and which latter, no doubt, have passed through many short periods of æstivation during their period of growth, which was frequently interrupted by the dry spells between showers. Probably from the repeated æstivation periods that these dwarfed forms must pass through, there has been produced an actual decrease in the size of the embryo, as is indicated by the reduction in the size of the protoconch; and this may mark the fixing of the small race, even though their environment may change; but this dwarfing of the embryo is not needed to explain the reduction in size.

The change of sculpture which accompanies the reduction in size is to be differently explained in the case of each species. In the one case, that of *L. granulosa,* it has been shown to be directly connected with the reduction in size, which in turn is brought about by the loss of a whorl. The sculpture in this case is that of the young shell up to the beginning of the sixth whorl (up to 5.3 whorls generally), and is a necessary accompaniment of the loss of a whorl. In the case of normal forms in which this sculpture exists, as in the occasional specimens from Somerset or the Swift Collection specimen of *L. granulosa,* this sculpture seems to have persisted up to the end of the sixth whorl; and, as pointed out, it may be an ancestral character which is becoming obsolescent. But it has been rejuvenated in these dwarfed forms by the process known as reversion.

The case of the change of sculpture in the dwarfed forms of *L. aureola* is different. Here we are not dealing with a character which exists in the young stages and is simply disclosed by the leaving off of a whorl, as in the last case, but with a new character of which no trace is to be found in the young of the normal species. It may be an adaptation in response to the change of environment or it may be due to the effect of hybridity. It is here that the evidence is incomplete.

It is not known whether the other form that would likely hybridize with *L. aureola* occurs (or has occurred) at Montego Bay. I mean the species *L. granulosa.* In a large collection made at Montego Bay in 1910 I did not encounter this species, nor is it found in Henderson's list[6] as being found at this point. It might be found in some of the deposits of semi-fossil shells that occur near Montego Bay, but while I examined these, I did not find any specimens of *L. granulosa.* If it existed at Orange Hill and at Rose Mount previous to the clearing of the land it would probably die out, as this species requires more cover than is to be found in the logwood-planted pastures where the Montego Bay race of *L. aureola* is now living. And during its extinction it might very conceivably have mixed with the *L. aureola,* which thrives well in grass lands elsewhere in the island. The hybrid thus produced would be likely to have a tuberculated periphery. And the hybrid living with a normally sculptured, pure race of *L. aureola* would tend through hybridity to change back to the normal sculpture of this latter species.

[6] J. B. Henderson, *Nautilus,* VIII, 1894, pp. 1, 19, 31.

On the other hand, the variation may be a response to change of environment, the animals becoming adapted to arid conditions. Of course, this adaptation is evident as regards the reduction in size, but it is not yet known that animals living with deficiency of moisture necessarily become more or differently sculptured. The chief effect of this aridity would be to reduce the moisture of the body, and this may conceivably produce an increase of sculpture. Reduction of moisture followed by an increase of moisture tends to induce proliferation. This has been noted by Loeb[7] in the case of the eggs of the sea urchin. When newly fertilized eggs are placed in hypertonic sea water for three or four hours and then brought back into normal sea water, they divide into from six to sixteen cells in about ten minutes, and in some cases even into about forty cells inside of twenty minutes. The reduction of moisture in the egg was here sufficient to inhibit cell division, but not enough to prevent nuclear division. When put back into normal sea water, a most powerful streaming of the protoplasm was observed. This streaming seemed to occur around the chromosomes and fragments of nuclear matter as centres. At length each knob or projection formed by the streaming became a separate cell. The effect of the hypertonic sea water (made by adding salt to normal sea water) was to withdraw water from the cell. Putting the egg back into normal sea water added water to the cell. Æstivation must result in withdrawal of water from the protoplasm, and may proceed to the point of gelation. Addition of water to the protoplasm after such æstivation, might readily result in proliferation as a result of the irregular nuclear division produced during the æstivation period when cell division could not occur. The irregular thickening of the shell that forms the peripheral tubercles and other increase of sculpture is of the nature of a proliferation of the shell. This is conceivably due to the irregular cell division produced by aestivation, which in turn is preceded by nuclear division without accompanying cell formation during the æstivation period. Normally a cell dividing produces two daughter cells, but under this fluctuation of the water content the number of daughter cells may be from six, eight, etc.; or M=2D may become M=4D (or 6D or 8D, etc.).

Boveri[8] has shown that the conditions which bring about cell division seem to depend upon a ratio between the mass of the chromosomes to the mass of protoplasm being established, and occurs

[7] Loeb, *Jour. of Morphology*, Vol. 7, p. 253, 1892.
[8] Boveri, *Zellen Studien*, Heft 5, Jena, 1905.

when the ratio chromosomes to protoplasm reaches a certain constant. Increase of the mass of the chromosomes retards cell division, which does not occur until the mass of the protoplasm increases also. The material for the growth of the chromosomes is furnished by the protoplasm, from its "reserve material," according to Sachs. So cell growth consists in the transformation of protoplasmic into chromatin material in the nucleus until a definite ratio of $P : C = k$ is reached, when division occurs. The mother cell just before division consists of $nC \div P = M$. After division M divides into 2D each being $nC' \div P'$. These daughter cells then grow to the size and ratio of the mother cell, or until $nC' \div P'$ becomes $nC \div P$, when division may again occur. Starvation produces a reduction in the amount of protoplasm and retards the development of the chromosomes. Æstivation will cause reduction in the amount of protoplasm and retard cell division. J. Sachs was the first to point out that in each species the ultimate size of the cell is a constant for each organ and that where two individuals differ in size, the difference is in the number and not the size of corresponding cells. Amelung, a student of Sachs, confirmed this by actual count. But it seems probable that diminution in the amount of protoplasm may be accompanied or followed by a reduction in the mass of the chromosomes and reduction in the size of the nuclei, and as the ratio $C \div P$ is constant for cell division, then $C \div P = M$ by reduction of mass of both C and P to C′ and P′ becomes $C' \div P' = M'$, a smaller cell. It is in this way that the observed reduction in size of the embryonic shell or protoconch in these dwarfed forms of the two species of *Lucidella* here considered is to be explained. For this reduction in size of the protoconch must accompany a reduction in the size of the egg, and it is probably the establishing of a new equilibrium resulting in the reduction in size of the egg (among other things) that is the explanation of the observation that conditions unfavorable to the growth of the animal are not unfavorable to its reproduction.

## Explanation of Plate I.

It is to be noted that figures 1–6 are enlarged somewhat more than the rest, being magnified 4.5 times, while all the other figures (7–26) are magnified 3.4 times, and these being all on the same scale, the relative sizes may be directly compared. Figs. 7–10 are normal; 11–15 are dwarfed; figs. 16–21 are normal; 22–26 dwarfed.

Figs. 1, 2, 3.—*Lucidella granulosa* C. B. Adams (Swift Collection). Showing the tuberculated and keeled periphery characteristic of the specimens in this lot.

Fig. 4.—*Lucidella granulosa* C. B. Adams. A form with the last whorl smooth, from Somerset.

Fig. 5.—A specimen of the same species from Somerset, which shows the tuberculated keel as in figs. 1–3.

Fig. 6.—A specimen of the same species from Somerset Road colony with nearly smooth last whorl, but showing the tuberculation on the earlier whorls.

Figs. 7–9.—Three specimens of *L. granulosa* from Somerset, with smooth last whorl. Figs. 7 and 9 show two common color patterns.

Fig. 10.—A specimen of *L. granulosa* rom Somerset Road, with smooth last whorl.

Figs. 11, 12.—Two of the dwarfed forms of *L. granulosa* from the Sturridge place. Both show the granulated periphery of the last whorl.

Figs. 13–15.—Three of the dwarfed specimens of *L. granulosa* from the Kendal Road colony. They all show the granulated periphery.

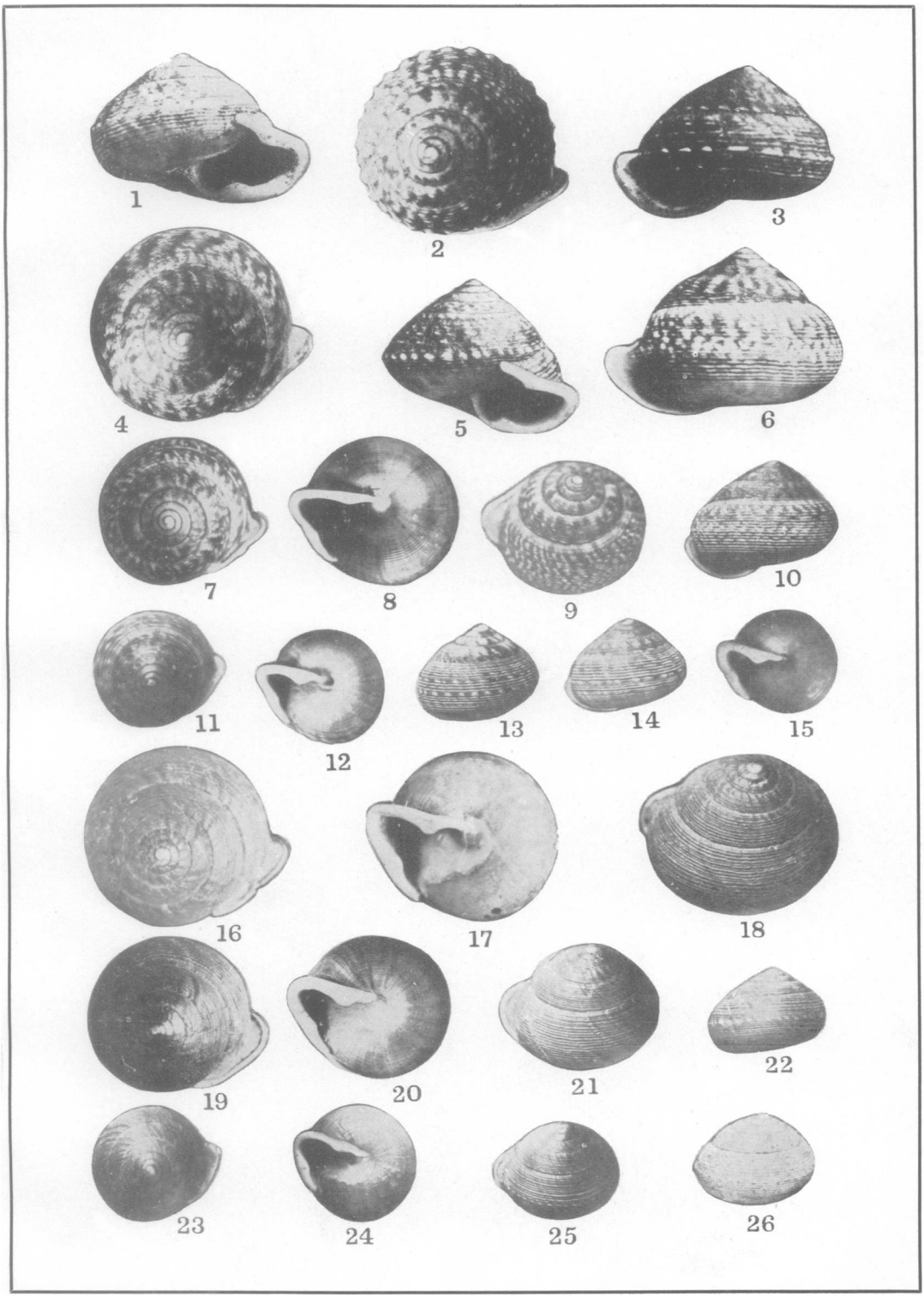
Figs. 16–18.—*Lucidella aureola* (Fér.) from Somerset, showing the rather large, normal form of this species as found at this locality.

Figs. 19–21.—*Lucidella aureola* (Fér.) from the Santa Cruz Road, showing the smaller size of the specimens from this station as compared with those from Somerset.

Fig. 22.—*Lucidella aureola* (Fér.) from Orange Hill, Montego Bay; the form with tuberculate periphery.

Figs. 23, 24.—*Lucidella aureola* (Fér.) from Orange Hill, Montego Bay, the shell seen from above and from the under side.

Figs. 25, 26.—*Lucidella aureola* (Fér.) from Orange Hill, Montego Bay, each showing the tuberculate periphery of the form for which the varietal name of *Montegoensis* is suggested.




BROWN: VARIATIONS IN LUCIDELLA.